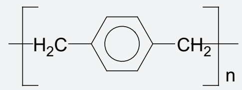
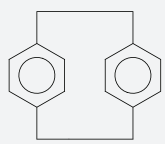
PPX poly(p-xylylene)

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	poly(p-xylylene)	
IUPAC name	-	poly(1,4-phenyleneethylene)	
ACS name	-	poly(1,4-phenylene-1,2-ethanediyl)	
Acronym	-	PPX	
CAS number	-	25722-33-2	
Linear formula			
HISTORY			
Person to discover	-	Michael Szwarc, William Gorham	
Date	-	1947, 1965	
Details	-	Michael Szwarc was able to identify PPX in products of decomposition of p-xylene. William Gorham developed its synthesis from di-p-xylylene, and Union Carbide commercialized it in 1965.	
SYNTHESIS			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	1633-22-3	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	208.3	
Method of synthesis	-	chemical vapor polymerization: paracyclophane is evaporated at 150-180°C in vacuum. Pyrolysis at 680-700°C is the next stage in which diradicals are formed. The reactive vapor polymerizes on a cold surface kept at ambient temperature. A similar method is used for production of copolymers. It is generally referred to as chemical vapor deposition	Fink, J K, High Performance Polymers, William Andrew, 2008; Smalara, K; Gieldon, A; Bobrowski, M; Rybiscki, J; Czaplewski, C, J. Phys. Chem., 114, 4296-4303, 2010; Pu, H; Jiang, F; Wang, Y; Yan, B, Colloids SurfacesA361, 62-65, 2010.
Temperature of polymerization	°C	680-700	
Pressure of polymerization	Pa	13.3	
Yield	%	24-26	
Mass average molecular weight, M_w	dalton, g/mol, amu	190,000-500,000; 500,000 (Parylene N)	
Polymerization degree (number of monomer units)	-	2,000-4,000	
Molar volume at 298K	cm^3 mol^{-1}	87.5 (crystalline)	
Van der Waals volume	cm^3 mol^{-1}	63.8 (crystalline)	
STRUCTURE			
Crystallinity	%	35-66	
Cell type (lattice)	-	monoclinic (α form); trigonal (β form)	
Cell dimensions	nm	a:b:c=0.592:1.064:0.655; a:b:c=2.052:2.052:0.655	

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PARAMETER	UNIT	VALUE	REFERENCES
Unit cell angles	degree	β=134.7; γ=120	
Number of chains per unit cell	-	2; 16	
Lamellae thickness	nm	10-25	
COMMERCIAL POLYMERS			
Some manufacturers	-	Specialty Coating Systems	
Trade names	-	Parylene N	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	1.11	
Color	-	transparent	
Refractive index, 20°C	-	1.59-1.6690	
Birefringence	-	0.000069-0.000235	Senkevich, J J; Desu, S B; Simkovic, V, Polymer, 41, 2379-90, 2000.
Melting temperature, DSC	°C	400-427	
Decomposition temperature	°C	<425	
Thermal conductivity, melt	W m^{-1} K^{-1}	0.13	
Glass transition temperature	°C	230-240; 13 (amorphous)	
Specific heat capacity	J K^{-1} kg^{-1}	837	
Long term service temperature	°C	expected to survive exposure to 100°C for 10 years	
Dielectric constant at 100 Hz/1 MHz	-	2.6-2.8/2.8	
Dielectric loss factor at 1 kHz	-	0.002	
Dissipation factor at 100 Hz	E-4	2	
Dissipation factor at 1 MHz	E-4	6	
Volume resistivity	ohm-m	1E13 to 1.4E15	
Surface resistivity	ohm	1E13	
Electric strength K20/P50, d=0.60.8 mm	kV mm^{-1}	276	
Coefficient of friction	-	0.25 (static and dynamic)	
Surface free energy	mJ m^{-2}	46.3	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	45-62; 3,000 (high strength fiber); 19,000-23,000 (theoretically calculated values)	
Tensile stress at yield	MPa	42.1	
Tensile creep modulus, 1000 h, elongation 0.5 max	MPa	43	
Elongation	%	40*-140	
Young's modulus	MPa	2,100-14,000; 102,000 (high strength fibers); 280,000 (theoretically calculated value)	Lee, C, Solid State Technol., 28-33, Nov. 2008.
Rockwell hardness	R	85	
Water absorption, equilibrium in water at 23°C	%	0.1, 0.01 (24 h)	

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PARAMETER	UNIT	VALUE	REFERENCES
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	good	
Alcohols	-	very good	
Alkalis	-	good	
Aliphatic hydrocarbons	-	very good	
Aromatic hydrocarbons	-	very good	
Esters	-	very good	
Greases & oils	-	very good	
Halogenated hydrocarbons	-	good	
Ketones	-	very good	
Good solvent	-	chlorinated biphenyl, methylene chloride, chloroform, toluene	
WEATHER STABILITY			
Spectral sensitivity	nm	266 (laser ablation); <340	Bera, M; Rivaton, A; Gandon, C; Gardette, Eur. Polym. J., 36, 1765-77, 2000; Jeong, Y S; Ratier, B; Moliton, A; Guyard, L, Synthetic Metals, 127, 1-3, 189-93, 2002.
Products of degradation	-	methylene group oxidation, chain scission	Bera, M; Rivaton, A; Gandon, C; Gardette, Eur. Polym. J., 36, 1753-64, 2000.
PROCESSING			
Typical processing methods	-	coating, vapor deposition	
Applications	-	bobbins, electronics (capacitors, circuit boards, cores, fiber optic components, magnets, power supplies, relays, semiconductors), heat exchangers, medical (implants, needles, pacemakers, stents, surgical instruments), metal primer (derivative), probes	
Outstanding properties	-	barrier properties, easy processing, insulation properties	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	water – 1633; =C-O-C – 1017; CH – 960	Wu, X; Shi, G; Qu, L; Zhang, J; Chen, F, J. Polym. Sci. A, 41, 449-55, 2003.